PB86-119880

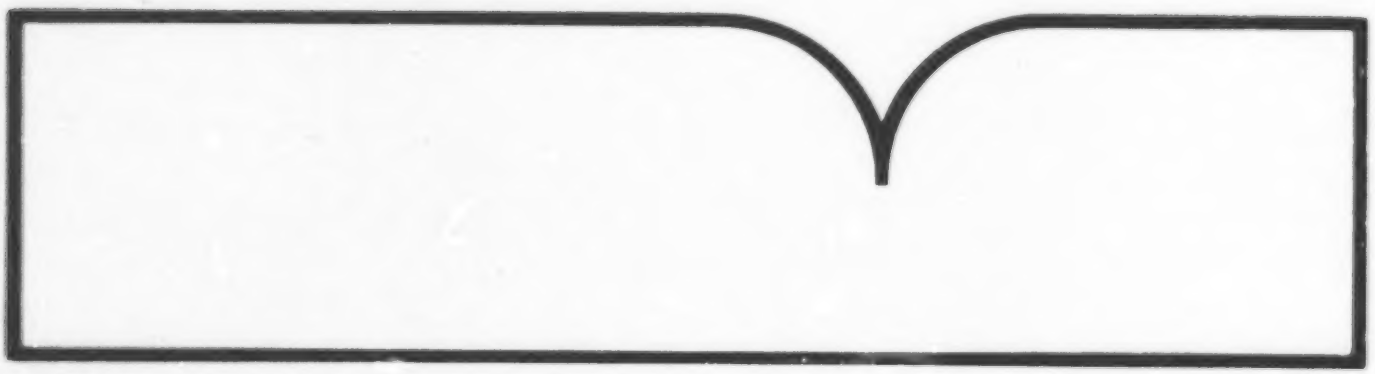
Highlights from Technical Manual on Hood System Capture of Process Fugitive Particulate Emissions

Research Triangle Inst.
Research Triangle Park, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Oct 85



U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-119880

EPA/600/D-85/256
October 1985

HIGHLIGHTS FROM TECHNICAL MANUAL ON HOOD SYSTEM CAPTURE OF PROCESS FUGITIVE PARTICULATE EMISSIONS

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/D-85/256		

4. TITLE AND SUBTITLE	5. REPORT DATE
Highlights from Technical Manual on Hood System Capture of Process Fugitive Particulate Emissions	October 1985
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) E. R. Kashdan, D. W. Coy, J. J. Spivey (RTI); T. Cesta, H. D. Goodfellow (Hatch Associates, Ltd); and D. L. Harmon (EPA/AEERL)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Research Triangle Institute P. O. Box 12194 Research Triangle Park, North Carolina 27709	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-3953
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Published paper; 14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Dale L. Harmon, Mail Drop 61, 919/541-2429.

16. ABSTRACT The paper discusses a technical manual whose emphasis is on the design and evaluation of actual hood systems used to control various fugitive particulate emission sources. Engineering analyses of the most important hood types are presented to provide a conceptual understanding of the design process, consisting of identification of source parameters, calculation procedures, and techniques for evaluating hood performance. Some of the design techniques have been introduced in technical papers by Hatch Associates and have been formalized in this manual. Case studies of actual hood systems not only illustrate the application of these design methods, but also identify their limitations. Several of the case studies are from the files of Hatch Associates and provide unique insight into the diagnosis of an existing system. The purpose of the manual is to provide regulatory officials with a reference guide on the design and evaluation of hood systems to capture process fugitive particulate emissions. Much of the hood design information is of necessity analytical, based on a mathematical or engineering approach. However, every effort has been made to explain the physical processes in qualitative terms and to separate the formal equations.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B 14F
Processing	Stationary Sources	13H 14B
Leakage	Fugitive Emissions	14G
Particles	Particulate	
Aerosols	Hoods	07D
Design Criteria	Engineering Analysis	
Engineering		
Analyzing		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	26
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

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INTRODUCTION-

Process fugitive particulate emissions have been defined as "particulate matter which escapes from a defined process flow stream due to leakage, materials charging/handling, inadequate operational control, lack of reasonably available control technology, transfer, or storage" (Jutze et al., 1977). Secondary hood systems consisting of enclosures, local hooding, or remote hooding are the practical means of capturing these emissions. Once captured, the gas stream can be ducted to high-efficiency air pollution control devices. Frequently, the capture efficiency of the hood is far less than the removal efficiency of the control device. Emissions missed by the hood usually escape to the atmosphere.

Considering the diversity of sources classed as process fugitives, it is not surprising that the design of secondary hood systems varies greatly; a large range is found in size, exhaust rate, and arrangement. Regulatory officials responsible for reviewing hood systems for either existing or planned sites face a difficult task. The behavior of process fugitive particulate plumes is complex. Process equipment interference may change plume dimensions and location, and in-building air currents may cause plume drift. As a result, the interaction of the hood and plume is not always predictable. Moreover, most of the traditional industrial ventilation texts do not consider process fugitive sources specifically. These texts have emphasized general design rules rather than a thorough understanding of hood design or the limitations of design methods. The emphasis of the technical manual (from which these highlights have been extracted) is on the design and evaluation of actual hood systems used to control various fugitive particulate emission sources. Engineering analyses of the most important hood types are presented to provide a conceptual understanding of the design process, which consists of identification of source parameters, calculation procedures, and techniques for evaluating hood performance. Some of the design techniques have been introduced in technical papers by Hatch Associates and have been formalized in this manual.

Case studies of actual hood systems not only illustrate the application of these design methods but also identify their limitations. Several of the case studies are from the files of Hatch Associates and provide unique insight into the diagnosis of an existing system.

The purpose of the manual is to provide regulatory officials with a reference guide on the design and evaluation of hood systems to capture process fugitive particulate emissions. Much of the hood design information is of necessity analytical, based on a mathematical or engineering approach. However, every effort has been made to explain the physical processes in qualitative terms and to separate the formal equations.

This paper provides highlights from the manual. General hood capture system design considerations are discussed. An example follows that illustrates the application of specific design methodology to low-level fugitive emissions from a primary copper converter.

GENERAL DESIGN CONSIDERATIONS FOR HOOD SYSTEMS

The hood designer's job is often viewed as nothing more than devising some convenient hood arrangement and estimating the required exhaust rate. These are actually only intermediate steps in a well-considered design process (Figure 1). The starting place for hood design is defining the design objectives clearly in quantitative terms. Once the objectives are understood and agreed upon, a thorough characterization of the process fugitive source must take place. Not only is a knowledge of the physical characteristics of the plume necessary during both average and peak conditions, but the process source should be examined in regard to measures to reduce emissions, planned process changes, and concurrent processes (equipment interference and in-building air currents, etc.) in the plant. Selecting a suitable hood type follows. At last, design methods come into play to provide hood dimensions and to estimate the exhaust rate required to meet the design objectives. Implicit in application of the design methods is evaluation of alternative hood arrangements and required exhaust flow rates. Technical and economic evaluations are used for optimization in the hood capture system design process. But the designer also is responsible for ensuring that the hood system after installation is reliable and accepted by all personnel.

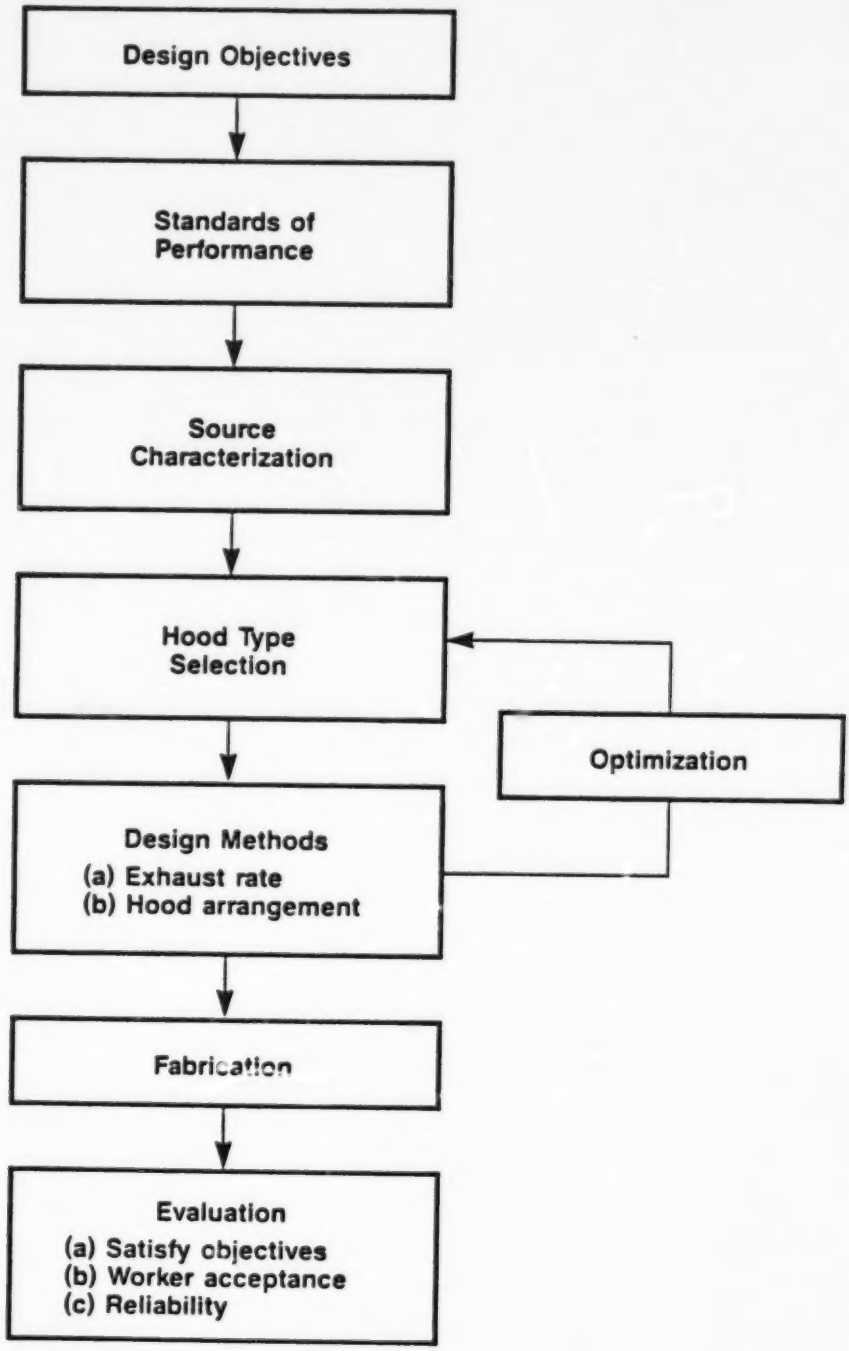


Figure 1. Summary of hood design process.

Hood systems are designed for one or more objectives. Typically, the objective is to reduce workplace contaminant concentrations, to reduce air pollution emissions, or to recover a product. In any case, it is essential to quantify the objectives in terms of standards (e.g., to meet a workplace exposure standard, to reach an acceptable opacity level for particulate matter escaping through roof vents, or to achieve a desired level of visibility in the plant). These standards then determine the expected performance of the hood system. Hood systems, planned or existing, must be evaluated with reference to the design objectives.

Attention now turns to the emission source to be controlled. Consideration should first be given to the possibility of eliminating or modifying the contaminant generation process itself. Even when hooding is used, changes to the process could reduce the amount of contaminant generated or simplify the hood design problems by altering the way that contaminant is dispersed. By the same token, the possibility of future changes in the process conditions must be considered as well. No hood design can accommodate increases in emission volume flow rates far in excess of the levels it was originally intended to control. Too frequently at this point, due consideration is not given to concurrent processes and activities in the plant. Inasmuch as every hood system is affected by air flow patterns within the building, drafts from opening bay doors or from various thermal processes can degrade hood performance. Stationary and/or moving overhead cranes are another disruptive factor for some hood systems that may alter plume dimensions or disperse the plume beyond hood boundaries. Recognition of these factors during source characterization provides the opportunity to design a hood system that can satisfactorily accommodate some disruptions, or take steps to reduce their impact on hood systems performance; e.g., use of partition walls to reduce cross-drafts.

Process fugitive particulate sources may be classed broadly as buoyant, nonbuoyant, or inertial. Buoyant sources are hot processes (many are 1000 °C or greater), giving rise to plumes with initial velocities on the order of 3 m/s. Nonbuoyant sources are cold processes, or at least not very hot; for the nonbuoyant source, the plume will not exhibit strong plume rise and is likely to be deflected easily even close to the source. Inertial sources are nonbuoyant, but, in addition, consist of high concentrations of coarse particulate matter. The motion of the particulate matter entrains additional air and determines the behavior of the inertial plume.

Although many names are used to type hood systems, hoods are most conveniently classified in relation to the emission source they control. Three hood types may be distinguished: enclosures, exterior hoods, and receiving hoods. Enclosures completely surround the source of emissions. Obviously, from the standpoint of capture efficiency, enclosures are the preferred method of control because escape of emissions is limited to leaks through openings. However, enclosures are not always suitable, especially in cases requiring ready access to the process source. Exterior hoods (also referred to as perimeter and captor hoods) are so called because they are exterior to the source. Exterior hoods function by inducing air flow toward the suction opening. Because the "reach" of such hoods is limited, exterior hoods are always local (i.e., close to the source). Receiving hoods are intended to act as receptors to particulate plumes that, by virtue of the process source, possess significant motion. Receiving hoods may be local or remote from the source (a canopy hood is one kind of receiving hood). An important special case is a hood system that uses air jets to assist in the capture of particulate emissions. This design in this manual is termed an "assisted exterior hood" (push/pull hood) because the hood system (not the process) directs the motion of the particulate plume.

Selection among the three hood types is limited by the above source classification. Other factors limiting the selection include: planned or existing site, access to the process, amount of clear space around the emission source, and constraints on operating costs and/or fan capacity. A summary of the general principles for designing the different hood types is provided in Figure 2. From the standpoint of hood capture efficiency, enclosures are always preferable to local hoods which, in turn, are preferable to remote hoods. For large-scale inertial sources (e.g., materials handling), enclosures are practically the only choice. Nonbuoyant sources most often are controlled by local hoods. Remote hoods may be used on buoyant sources and frequently are. When planning controls for a buoyant source, however, enclosures or local hooding should be considered.

Characterization of the process fugitive particulate source is necessary to design the hood type selected. Among the important source parameters are continuous or intermittent plume, plume flow rate, plume geometry, source heat flux, source geometry, physical/chemical characteristics of the particulate

General Design Principles for Hood Systems

- **Design Objectives**

  Principle: All hoods must be designed to satisfy certain standards of performance.

- **Selection of Hood Type**

  Principle: The nature of the process fugitive emissions and access to the process determine the selection of the hood.

- **Source Characterization**

  Principle: A thorough knowledge of the process source parameters is essential to the successful design of a hood system.

- **Exterior Hoods**

  Nonbuoyant sources: Required exhaust rate is based on contour surface and capture velocity.

  Buoyant source: Required exhaust rate may be determined from momentum considerations.

- **Receiving Hoods**

  Inertial source: Best hood arrangement is such that hood opening coincides with particle trajectory.

  Buoyant source: Local capture requires knowledge of heat generation rate and gas temperature. Remote capture requires estimation of the direction and quantity of thermally induced air flow.

- **Enclosures**

  Inertial source: Required exhaust rate is based on air flow induced by the motion of the materials and consideration of dust-producing mechanisms.

  Buoyant source: Design is based on considerations similar to local receiving hoods.

Adapted from Hemeon, 1963, p. 67.

Figure 2. Summary of general design principles.

matter (especially particulate concentration), gas composition, gas temperature, and layout of the plant. For existing sites, these source parameters may be measured directly. For planned sites, values of the source parameters might be estimated, or data from similar plants may be used.

Design methods use the source parameter values above in various ways to obtain the necessary exhaust rate and dimensions of the hood. Any one, or combination, of five different design methods may be used. In increasing order of sophistication, they are:

1. Design by precedent
2. Design by rule-of-thumb
3. Design by analytical methods
4. Design by diagnosis of an existing site
5. Design by physical scale model.

In design by precedent, a working hood system that performs satisfactorily is copied. Although this method is simple, it can be powerful in producing a design that performs satisfactorily. However, in using this method, working designs that use excessive exhaust, and are therefore overdesigned, may be copied. Failures using this method will be because the copied system does not match the source parameters of the system under design.

In design by rule-of-thumb, working systems are surveyed and the elements common to most of them are put together to form a working design rule(s). This method is straightforward, but the design rule(s) is likely to oversimplify matters and may result in unacceptable performance. Alternatively, following the design rule(s) may result in a hood system that performs satisfactorily but uses excessive exhaust.

Design by analytical methods uses a mathematical model to predict hood exhaust rate and dimensions from the source parameters. Examining hood systems is not necessarily part of this method.

Design by diagnosis of an existing system is more specialized than the other methods. An existing system usually is not performing satisfactorily. Extensive observations and measurements are made to assess the hood design. Depending on the results, certain remedies may be applied to the hood system or an entirely new design may be necessary.

Lastly, design by physical scale model is the most sophisticated method and may be applied to existing or planned sites. The hood design is scaled hydrodynamically as a physical model using water or air as the test media.

As mentioned above, truly successful hood designs not only meet their expected performance standards, but remain reliable. Often times, hoods are placed in severe environments and are subject to extreme shocks, mechanical and thermal. Corrosion and erosion of the hood may also be factors. Fabrication techniques and choice of materials for the hood system therefore must be considered carefully. Acceptance of the hood system by operation and maintenance personnel cannot be overemphasized for ensuring ultimate reliability of any hood system.

SAMPLE CASE STUDY: AIR CURTAIN SYSTEM FOR COPPER CONVERTER SECONDARY EMISSION CAPTURE

Source Description and Background

This case is an air curtain system installed on a primary copper converter for capturing low-level fugitive emissions. The installation is at ASARCO's Tacoma Smelter and is the first domestic full-scale prototype air curtain hood on this type of application. The air curtain capture efficiency was evaluated during an extensive testing program by PEDCo Environmental, Inc. (PEDCo, 1983). The results of this program have been used to describe the hood performance in a later section of this paper. The original air curtain design calculation was not available for assessment. A design approach is presented for an air curtain based on application of an analytical technique to the existing site. This case study is presented with English units. (An English to metric unit conversion table is provided.)

Copper converting is the process of transforming copper matte produced by a smelting furnace into blister copper. A Peirce-Smith copper converter is used and consists of a horizontal refractory-lined steel cylinder (13 ft in diameter × 30 ft long) with an opening in the center (the converter mouth). The converter vessel is rotated into various positions during its operation. Figure 3 shows the converter positions for charging, blowing, and skimming.

During converter blowing, oxygen-enriched air is passed through tuyeres into the shell interior. Emissions generated during blowing are captured by a primary hood and routed to a sulfur dioxide recovery plant. Fugitive emissions (not captured by the stationary primary hood) are generated during

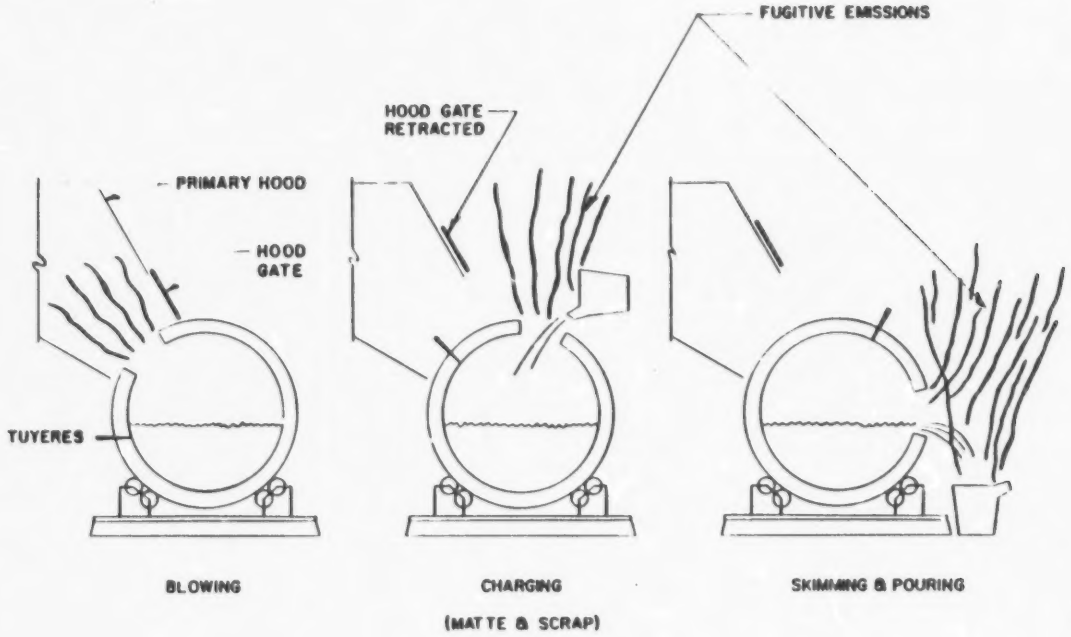


Figure 3. Copper converter operations.

converter charging, skimming, and pouring. During a typical 12-h converter cycle, secondary emission occurrences can total 30 min with an average duration of 4 min each.

Copper matte and cold scrap are charged by an overhead crane and ladle (a box may be used for scrap). Emissions during charging of cold scrap are the most severe.

When the converter is rotated out for skimming and charging, the primary hood gate is raised, and injection of air continues until the molten bath level is below the tuyeres. Similarly, before the converter is rotated back to the blowing position, the air is turned on. During these converter movements significant amounts of off-gases, blown out by the air, are released and contribute to the overall fugitive emissions.

The primary hood suction is switched off when air to the tuyeres is shut off. Therefore, no partial capture of fugitive emissions occurs through the primary hood.

Air Curtain Hooding System--

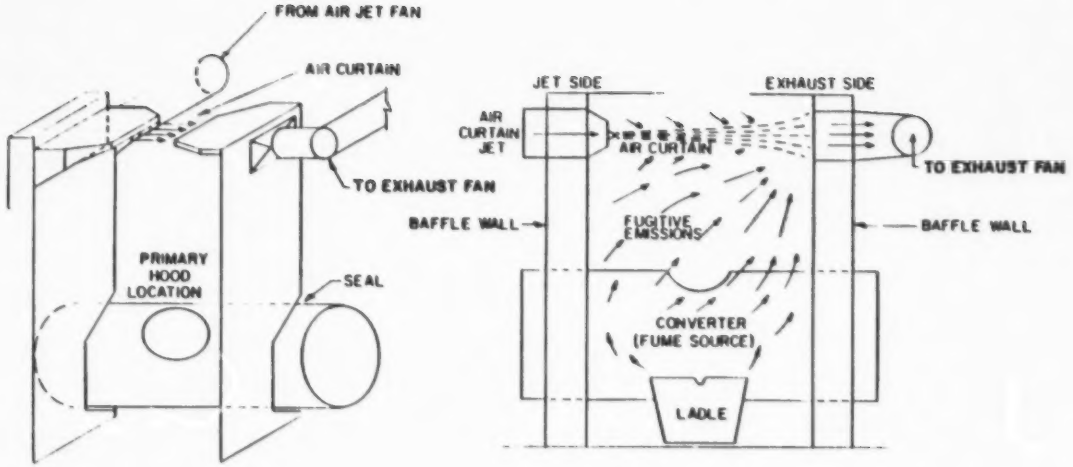
Four basic methods of converter secondary emission capture exist. These methods include enclosures, push/pull systems (air curtain), movable hoods, and fixed hoods. Regarding effectiveness, reliability, cost, maintenance, and operating interference, push/pull systems have been shown superior.

The air curtain as applied to the converter uses the principle of blowing an air jet across the open space above the fugitive source. Contact between the rising fumes and the air jet causes the fumes to be directed to a suction plenum located directly opposite. Figure 4 illustrates the copper converter air curtain system.

Regulatory Standards--

Regulations affecting the control of fugitive emissions are under the jurisdiction of both the Occupational Safety and Health Administration and the Environmental Protection Agency.

Under OSHA regulations, the intent is to provide an in-plant working environment that is relatively free of contaminants. Without secondary emission control (with building ventilation as the only means of diluting contaminant emissions) personnel are regularly exposed to contaminant levels above the OSHA standard. The contaminants of concern are sulfur dioxide, copper dust, lead, and inorganic arsenic.



Source: PEDCo, 1983.

Figure 4. Converter air curtain control system.

Under EPA regulations, the present intent is to maintain ambient air quality standards for sulfur dioxide. Sulfur dioxide ground-level concentrations in violation of ambient standards can result from fumigation by converter fugitive emissions. Opacity regulations, which promote zero visible emissions from process buildings during all operating conditions, would also be violated by uncaptured fugitive particulate emissions.

Successful operation of a capture hood for converter secondary emissions certainly can satisfy indoor regulations and also ambient regulations if captured emissions are cleaned and/or dispersed to acceptable levels.

Design Approach

The original air curtain design calculation was not available for this assessment; therefore, the following design procedure is based on application of an analytical technique to the existing site. This same approach has been used successfully to design the air curtain hood component of various electric arc furnace enclosures.

General Analytical Design Methodology

The use of air jets in hood designs is not a new concept. This section is concerned with the use of air jets to direct a buoyant plume into an exterior hood arranged laterally to the source. The topic of air jets was examined theoretically by Baturin (1972), practically by Hemeon (1963), and, most recently, in an excellent report by Yung et al. (1981).

Some preliminary concepts and definitions need to be addressed first. A series of air jets, or continuous blowing slot, is called an "air curtain," and for this particular application, an air curtain, not a single jet, would be necessary to direct a buoyant plume. The term air curtain frequently provokes the misconception that the air jets create a semi-solid barrier that the fugitive particulate matter cannot cross. This notion is false (Hemeon, 1963). An air curtain acts by entraining surrounding air. When used above a buoyant source, the air curtain will entrain the contaminated air, resulting in a calculable concentration of particulate matter in the air curtain. If the exterior hood, arranged to act as a receiving hood for the air curtain, fails to provide either adequate exhaust or face area to accommodate the flow rate and width of the curtain at the hood face, then the contaminant will not be captured.

An idealized, assisted exterior hood arrangement is shown in Figure 5(a). The design equations are derived from momentum considerations. This analysis is restricted to "jet throw distances" (equivalent to source width in this arrangement) less than six slot lengths, which can be taken as a practical limit. Beyond that distance, the shape of the jet becomes circular and is of limited use for hood capture. The applicable momentum diagram is shown in Figure 5(b). First, it should be recognized that momentum is conserved at every section away from the jet so that the total rate of air flow in the stream in relation to the primary flow from the nozzle is found by applying the following momentum conservation equation:

$$(\rho_o)(V_o^2)(A_o) = (\rho_x)(V_x^2)(A_x) \qquad (1)$$

where

ρ = jet air density (kg/m^3, lb/ft^3)

V = average jet velocity (m/s, ft/s)

A = jet cross-sectional area (m^2, ft^2)

$(\rho_o)(V_o^2)(A_o)$ = momentum flow rate at the nozzle (m·kg/s^2, ft·lb/s^2)

$(\rho_x)(V_x^2)(A_x)$ = momentum flow rate at distance x from the nozzle (m·kg/s^2, ft·lb/s^2).

Considering the geometry shown in Figure 5(b), the required jet nozzle velocity may be found from the following equation:

$$V_j = V_u \sqrt{\frac{(A_u)(T_j)}{(A_j)(T_u)} \cdot \frac{1}{C_H}} \qquad (2)$$

where

V_u = average plume updraft velocity (m/s, ft/s)

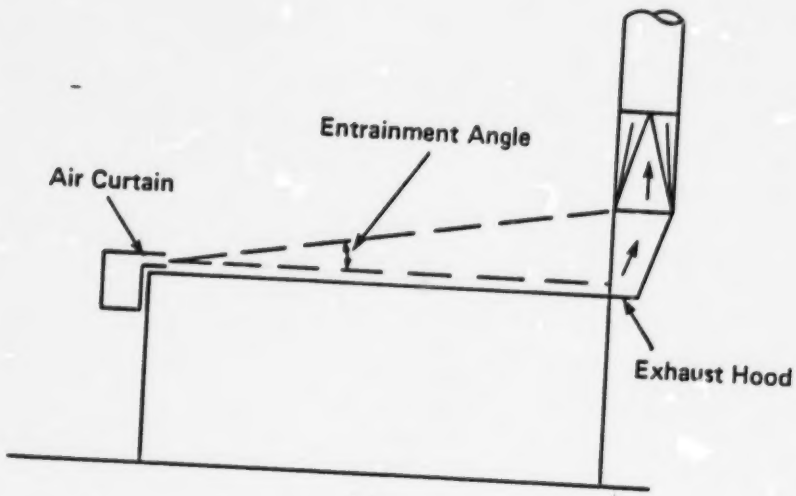
A_u = plume cross-section at intersection with jet (m^2, ft^2)

A_j = jet nozzle area (m^2, ft^2)

T_j = jet air temperature (K, R)

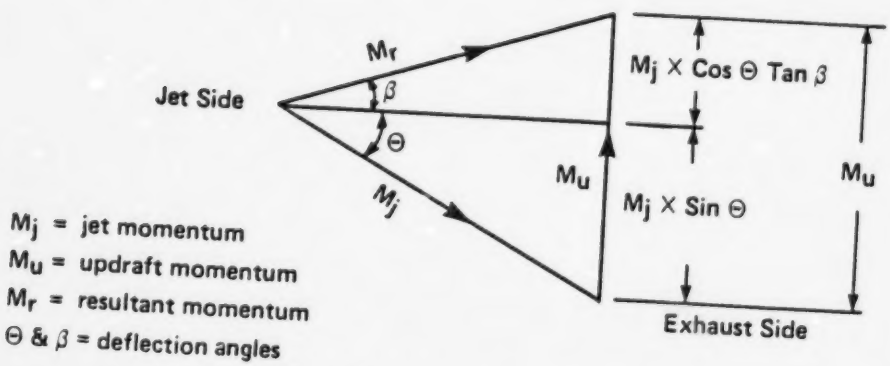
T_u = average plume air temperature (K, R)

C_H = (cos Θ × tan β) + sin Θ.



(a)

Adapted from ACGIH, 1976.



M_j = jet momentum
M_u = updraft momentum
M_r = resultant momentum
Θ & β = deflection angles

(b)

Figure 5. Assisted exterior hood for buoyant source and analysis.

The entrained air volume at the exhaust hood is calculated by using the governing equation for a continuous slot or, equivalently, line jet (Bender, 1979):

$$Q_s = 0.88 \sqrt{(Q_j)(V_j)(X)} \quad \begin{matrix} (m^3/s/\text{unit length of slot}, \\ ft^3/s/\text{unit length of slot}) \end{matrix} \qquad (3)$$

where

Q_s = hood suction rate (m^3/s, ft^3/s)

Q_j = jet nozzle flow rate (m^3/s/unit length of slot, ft^3/s/unit length of slot)

V_j = jet nozzle velocity (m/s, ft/s)

X = entrainment distance (m, ft).

The entrainment distance is usually taken as the distance between the nozzle and exterior hood. The entrainment angle of the jet, which defines the boundaries of the jet, has been found experimentally to have an approximate value of 24 degrees (Bender, 1979). Figure 5(a) demonstrates that the minimum hood height is the entrainment distance multiplied by the tangent of the entrainment angle.

Recommended practices in the use of these equations are as follows. Because of the vector addition of forces, if the jet nozzle is directed horizontally, the resultant force always will be above the nozzle elevation. Consequently, the nozzle should be pointed downward at an angle of 15 to 25 degrees from the horizontal. Air jet velocities at the nozzle should not exceed 30 m/s to avoid excessive noise or energy consumption. Finally, the interaction of the air curtain and the exhaust hood can be complex, especially if the velocities of the suction field at the hood are of the same magnitude as the jet velocity values in the vicinity of the hood. Assisted exterior hood designs therefore often require considerable adjustments to the nozzle angles and slot widths to achieve acceptable performance.

Application of Design Methodology

The first step requires determination of the emission plume flow rate and velocity. The air curtain is then located by careful consideration of fume source characteristics and converter operating requirements. The final air

curtain configuration is determined by applying the theory of jet behavior from the above section.

Figure 6 shows the fugitive emission plumes originating from charging and skimming activities, with respect to the as-tested air curtain. The dimensions and location of the air curtain have been pieced together from sketchy information but are more than appropriate for verifying the air curtain design.

The volume and velocity of fume rising to the air curtain level during charging and skimming are predicted by using the following:

Heat release--Heat is released from the following locations:

1. converter mouth
2. hot metal stream
3. surface and sides of the ladle.

From fundamental heat transfer calculations, a heat release of approximately 150,000 Btu/min is determined for both charging and skimming. Buoyancy flux is calculated from:

$$F = \frac{(g)(q)}{(C_p)(T_o)(\rho_o)} \qquad (4)$$

where

g = gravity constant = 32.2 ft/s^2

q = heat transfer rate (Btu/min)

C_p = specific heat of air = 0.24 Btu/lb °F

T_o = absolute air temperature = 530 °R

ρ_o = air density = 0.075 lb/ft^3

$$F = \frac{150{,}000 \times 32.2 \times 3600 \text{ s}^2/\text{min}^2}{0.24 \times (460 + 70) \times 0.075} = 1.8 \times 10^9 \text{ ft}^4/\text{min}^3.$$

The resulting buoyancy flux is 1.8×10^9 ft^4/min^3.

Plume flow rate--The vertical distance between the virtual plume origin and the air curtain elevation from Figure 6 is 21 ft for charging and 38.5 ft for skimming. The plume flow rates are then calculated from:

$$Q = 0.166\ (Z)^{5/3}\ (F)^{1/3} \qquad (5)$$

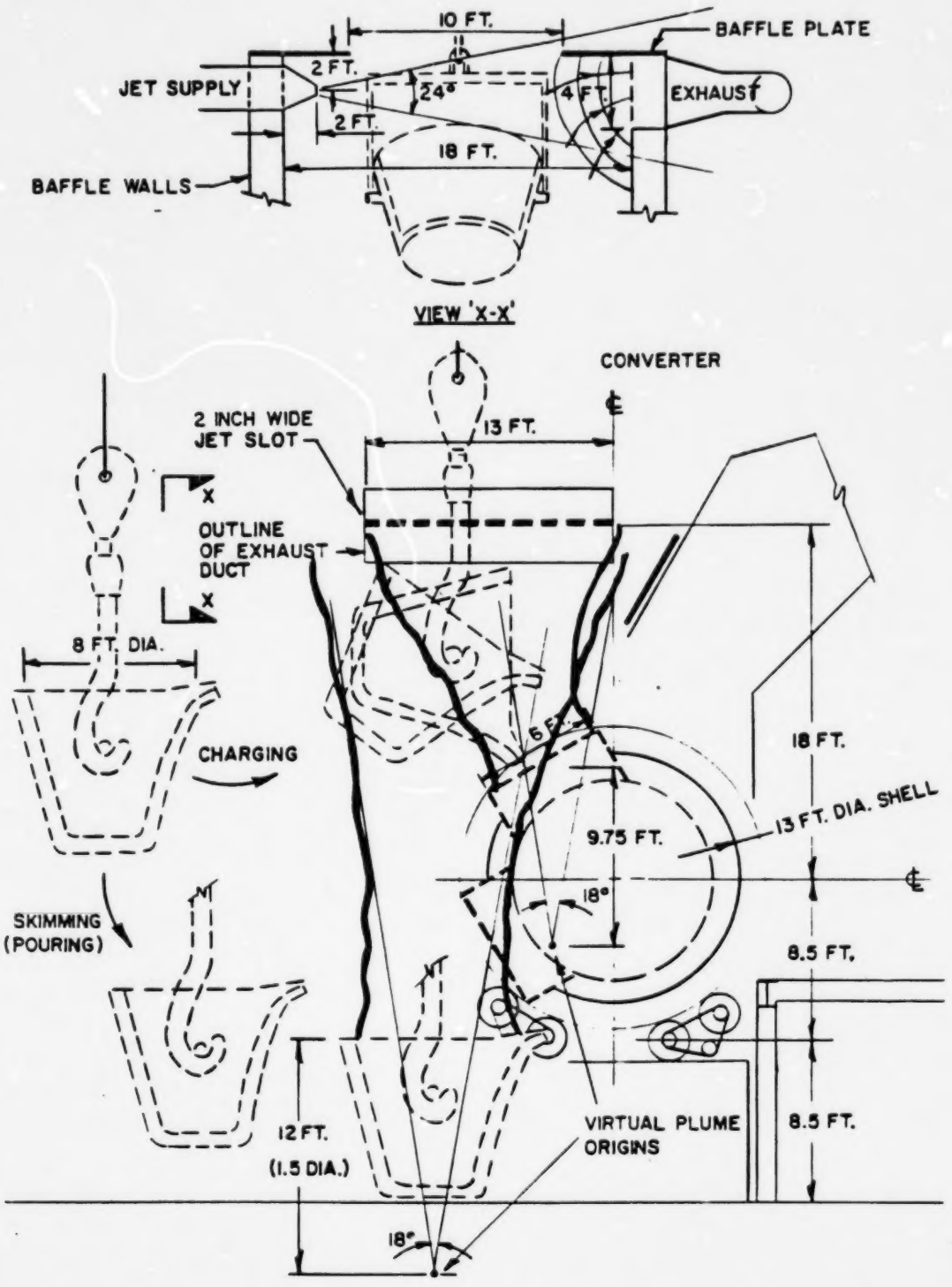


Figure 6. Analysis of air curtain system.

where

Q = plume flow rate at the hood face (acfm)

Z = effective height from the virtual plume origin to the hood face (ft)

F = buoyancy flux (ft^4/min^3)

charging: Q = 32,000 acfm at T = 480 °F

skimming: Q = 90,000 acfm at T = 185 °F .

T is calculated by a simple heat balance on the plume volume.

Plume velocity--The mean velocity of the rising air column at the intersection with the jet elevation is found by:

$V = Q \div A$ (plume cross-sectional area at the jet elevation).

For charging, the plume will spread around the ladle as it rises, and the cross-sectional area is based on a diameter of 10 ft (an ideal plume with an entrainment angle of 18 degrees cannot be assumed):

$$A = 10 \times 10 \times \frac{\pi}{4} = 79 \text{ ft}^2$$

$$\text{and } V = \frac{32{,}000}{79} = 410 \text{ ft/min} .$$

For skimming, the plume will spread under the influence of the hot converter shell, and a cross-sectional area based on a 15-ft diameter is assumed:

$$A = 15 \times 15 \times \frac{\pi}{4} = 177$$

$$\text{and } V = \frac{90{,}000}{177} = 510 \text{ ft/min} = 8.5 \text{ ft/s}.$$

The above analytical approach could be supplemented with data collected from plume photography in the case of an existing site.

Equation (2) can be used to calculate the required jet velocity. For the present case (Figure 6) assume angle $\beta = 0$ (Figure 5(b)). Set $\theta = 15$ degrees, and assume the worst design case of skimming where Q_u = 90,000 acfm, V_u = 8.5 ft/s, T_u = 185 °F (645 °R), and A_u = 176 ft^2. Assuming the jet slot width and length from Figure 6, and density, then:

Slot width = 2/12 ft

Slot length = 13 ft

T_j = jet air at ambient temperature of 70 °F (530 °R)

A_j = 2.166 ft^2

From Equation (2), V_j = 137 ft/s = 8,220 ft/min, and

Q_j = 2.166 × 8,220 = 17,800 acfm .

This compares to 18,000 acfm for the nozzle velocity on the as-tested prototype air curtain.

Next, the entrained air volume and jet velocity at the receiving hood are calculated by the governing equation for a line jet. Volume flow rate at distance R from the slot is represented by Q_H and is estimated by the equation (Equation 3):

$$Q_H = 0.88\ [(Q_j)(V_j)\ (R/\text{Slot length})]^{\frac{1}{2}}\ (\text{Slot length})$$

where

Q_H = plume arriving at hood face (acfm)

Q_j = jet flow rate at origin (acfm)

V_j = jet velocity at origin (ft/min)

R = distance from slot (ft).

The distance R is established by considering the influence of the exhaust plenum capture zone and the baffle plate. Entrainment is judged to occur between the jet and the edge of the baffle plate on the exhaust side. Beyond that point, entrainment is blocked by the upper baffle plate, and the plume updraft is captured by the influence of the exhaust off-take velocity field.

From Figure 6, R = 12 ft; therefore:

$$Q_H = 0.88 \times [(17{,}800/13) \times 8{,}200 \times 12]^{\frac{1}{2}} \times 13 = 133{,}000 \text{ acfm} .$$

To capture all the entrained air, the minimum exhaust volume would have to be 133,000 acfm. The hood as tested exhausts 126,000 acfm.

Using the above equation requires the assumption of a small density difference between the jet air and the air being entrained. In this case the average updraft temperature, estimated to be 185 °F as compared to jet air assumed to be at an ambient temperature of 70 °F, yields densities of 0.062 and 0.075 lb/ft^3, respectively, or a difference of about 20 percent. The

estimate of Q_H is therefore approximate. The core of the jet contains most of the intercepted fugitive gas, while the top fringe contains clean air; therefore, a partial exhaust of only 80 percent may be necessary for effective capture of fugitives.

By applying different nozzle angles and adjusting slot width, the overall design can be optimized with respect to minimizing jet and exhaust capacity.

Performance

An estimate of the air curtain capture efficiency and fugitive emission factors for the overall converter cycle and specific operational modes was performed by PEDCo Environmental, Inc., under U.S. EPA Contracts No. 68-03-2924 and 68-02-3546.

Three separate converter cycles were evaluated during the extensive test program. Hood capture efficiency was evaluated by three methods: tracer gas study, visual observations of opacity, and measurement of opacity. Fugitive emission factors were developed from measurement on emissions captured by the hood for the following: sulfur dioxide, particulate, selected trace elements, and particle size distribution. Table 1 summarizes the various hood capture efficiencies and the SO_2 fugitive emission factor for the overall cycle and specific modes that are pertinent for assessing the hood capture performance.

The main conclusions reached by the test program with respect to hood capture performance are:

1. A 90 percent or better fugitive emission capture was claimed achievable for the overall converter cycle and specific operating modes.

2. Converter and crane operations are significant variables in the generation and capture of fugitive emissions.

3. The fugitive emission generation rate is significantly greater during cold additions and rotating-in/rotating-out operating modes.

TABLE 1. SUMMARY OF HOOD CAPTURE PERFORMANCE

Operating mode	Hood capture efficiency (%) by tracer gas study		Hood capture efficiency (%) by visual observation of opacity		Measured opacity (%) above hood	Sulfur dioxide emission	
	A	B	Observer 1	Observer 2		Average lb/event	Average lb/min
Matte charge	94	62	94	91	14	9.5	2.19
Cold additions	99	62	95	85	21	32.0	7.38
Slag skimming	95	84	78	82	18	11.0	2.35
Copper pour	89	81	92	85	9	7.4	1.94
Rotate-in/rotate-out	--	--	77	76	--	23	6.15
Blow/idle	96	44	96	90	--	3.5	0.14
Overall	94.6	66.6	88.7	84.8	15.5	--	--

A = Tracer gas injection in upper control volume.

B = Tracer gas injection in lower control volume.

Note: Injection points in the lower control volume were immediately above or below the converter during charging, skimming, and pouring. Injection points in the upper control volumes were in the zone beginning above the converter and ending just below the exhaust hood face.

Adapted from PEDCo Environmental, Inc. (1984).

METRIC EQUIVALENTS

English	Times	Yields metric
°F	5/9 (°F-32)	°C
°F/min	0.556	°C/min
ton	907	kg
lb	0.454	kg
Btu/lb-°F	1.0	cal/g-°C
Btu/min	252	cal/min
cfm	1.7	m^3/hr
ft	0.30	m
ft^2	0.093	m^2
ft^3	28.32	L
ft/min	0.00508	m/s
in.	2.54	cm

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